Preliminary survey of backdrivable linear actuators for humanoid robots

Philippe Lucidarme[1], Nicolas Delanoue[1], Franck Mercier[1], Yannick Aoustin[2], Christine Chevallereau[2], Philippe Wenger[2]

[1]LARIS, 62 avenue Notre Dame du Lac, 49000 Angers, France,

[2]LS2N UMR CNRS 6004, 1 Rue de la Noë, 44300 Nantes, France

Romansy 2018
22nd CISM IFToMM Symposium on Robot Design, Dynamics and Control
June 25-28, 2018, Rennes, France
https://romansy2018.ls2n.fr/

Introduction

Experiment

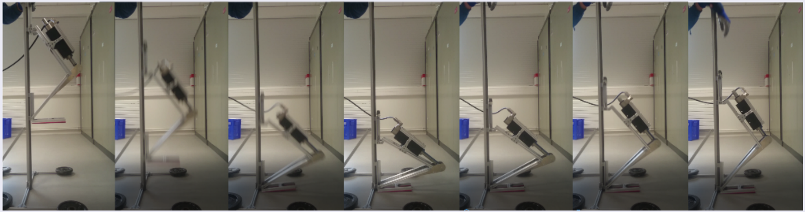


Figure: Experiment on cushioned landing of a 40cm high fall.

http://perso-laris.univ-angers.fr/~delanoue/b4d2/720p.mp4

Outline

Remark

To our point of view, cushioning is a crucial issue in humanoid robotics and remains a scientific and technological lock.

Remark

Indeed, most of robots tries to reach the ground with velocity zero in order to do not break the structure.

Definition

Backdrivability is the ability for bidirectional interactive transmission of force between input axis and output axis.

Shock absorption during impact

Spring	Hardware	Software

Shock absorption during impact

Spring 	Hardware	Software

Shock absorption during impact

Backdrivability \ Spring	Hardware	Software
Hardware		
Software (active compliance)		

Shock absorption during impact

Spring / Backdrivability	Hardware	Software
Hardware	Constant spring rate	
Software (active compliance)	Constant spring rate	

Shock absorption during impact

Spring / Backdrivability	Hardware	Software
Hardware	Constant spring rate	
Software (active compliance)	Constant spring rate Non-zero response time	Non-zero response time

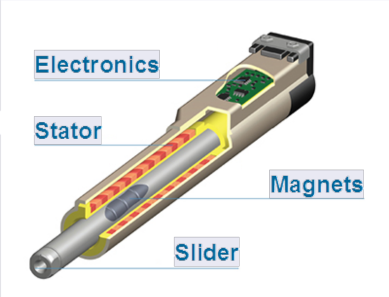
Shock absorption during impact

Backdrivability \ Spring	Hardware	Software
Hardware	Constant spring rate	
Software (active compliance)	Constant spring rate Non-zero response time	Non-zero response time

Shock absorption during impact

Backdrivability \ Spring	Hardware	Software
Hardware	Constant spring rate	Our approach
Software (active compliance)	Constant spring rate Non-zero response time	Non-zero response time

Direct drive linear actuator



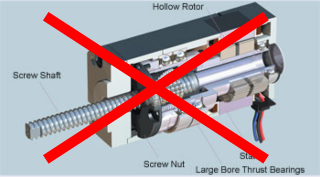


Figure: Sectional view of a direct-drive linear motor.

Direct drive linear actuator

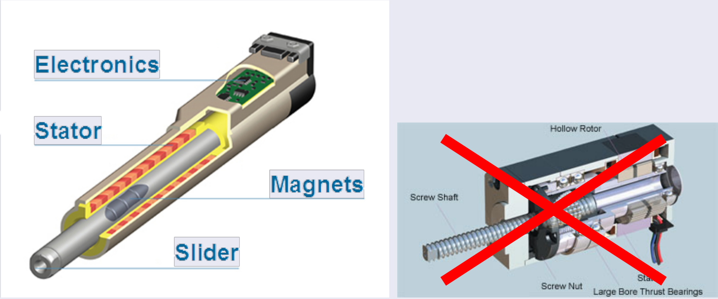


Figure: Sectional view of a direct-drive linear motor.

Classical linear actuator

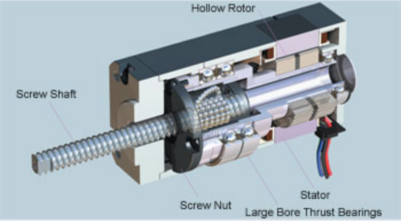


Figure: Sectional a “classical” linear motor.

Classical linear actuator

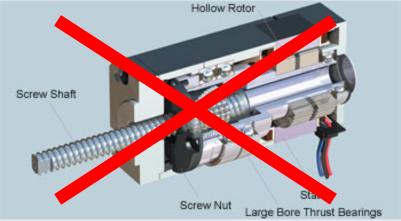


Figure: Sectional a “classical” linear motor.

Direct drive linear actuator

Figure: Photography of direct drive linear actuator (source LinMot®).

Numerical optimization

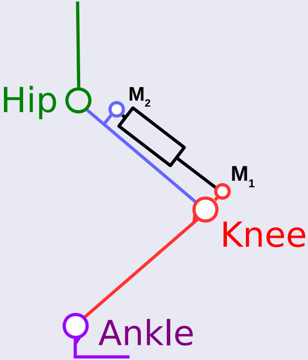
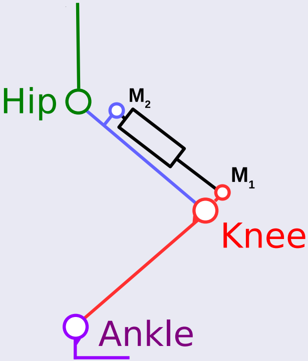


Figure: The single actuator architecture studied for this preliminary work (left).

Definition

A geometry is a specific positioning of the motors.

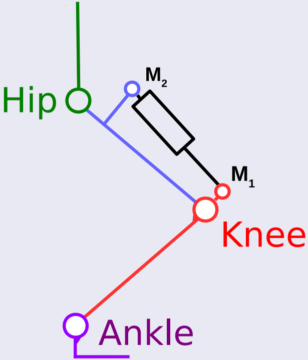
Example 1



Definition

A geometry is a specific positioning of the motors.

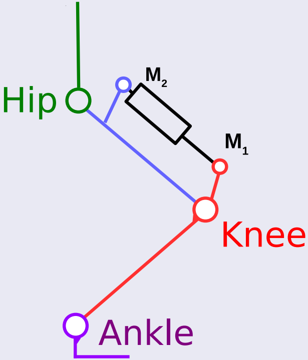
Example 2



Definition

A geometry is a specific positioning of the motors.

Example 3



Choose the best geometry in a finite dimensional family

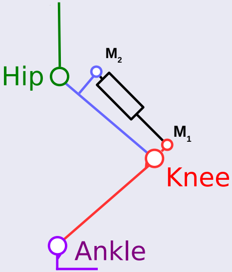


Figure: Parameters of the model and restricted areas for M_1 (green) and M_2 (purple).

Choose the best geometry in a finite dimensional family

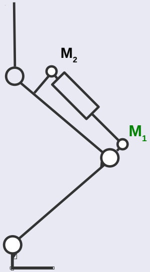


Figure: Parameters of the model and restricted areas for M_1 (green) and M_2 (purple).

Choose the best geometry in a finite dimensional family

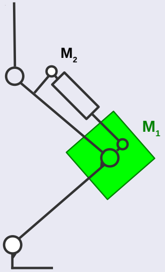


Figure: Parameters of the model and restricted areas for M_1 (green) and M_2 (purple).

Choose the best geometry in a finite dimensional family

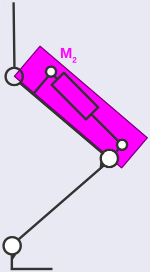


Figure: Parameters of the model and restricted areas for M_1 (green) and M_2 (purple).

Choose the best geometry in a finite dimensional family

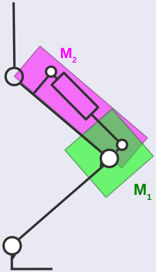
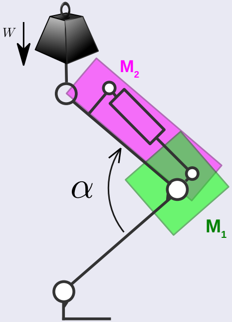


Figure: Parameters of the model and restricted areas for M_1 (green) and M_2 (purple).



$$\max_{M_1,M_2}\min_{\alpha}\ W(\alpha, M_1, M_2)$$

W is the supported weight, α is the knee angle.

Optimal solution of the optimization problem

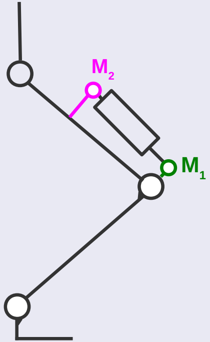


Figure: Optimal position of the motors

Comparison of optimization algorithms

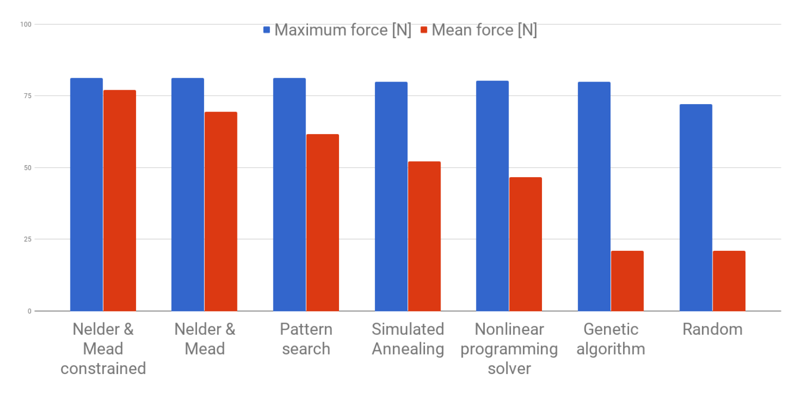


Figure: Comparison of optimization algorithms

Experimental results

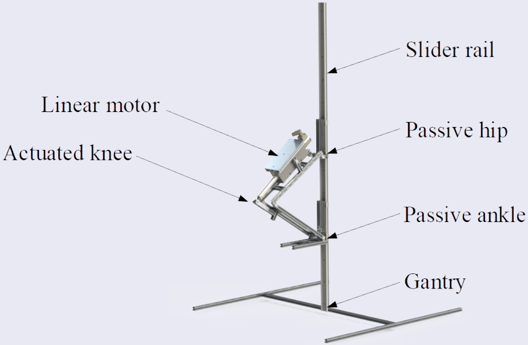


Figure: CAD model of the experimental setup.

Experimental results

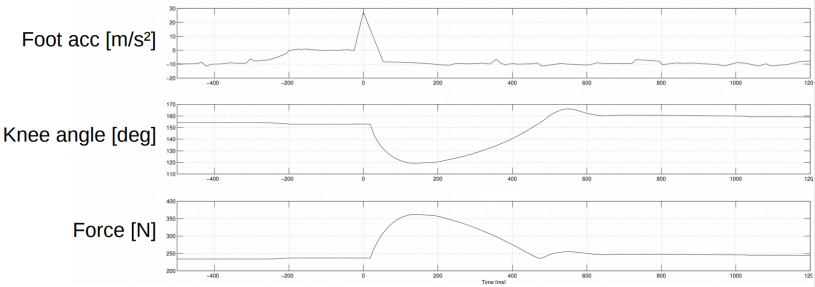
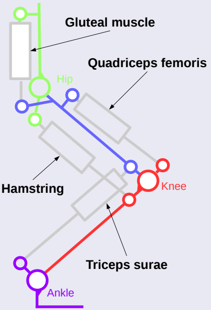


Figure: Experiment on cushioned landing of a 40cm high fall.

Conclusion

- We have designed and built a leg with a backdrivable actuator : “hardware compliance” and “electrical spring”.
- The system is successfully able to deal with high impacts.
- The motion is clearly a flexible and natural cushioning like human beings.

Future work


Gluteal muscle
Quadriceps femoris
Hip
Hamstring
Knee
Triceps surae
Ankle

Future work

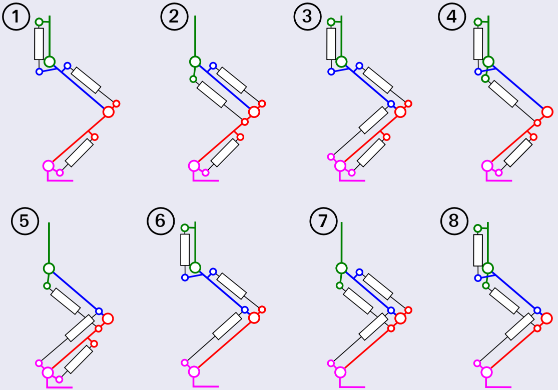


Figure: Different architectures

Thank you for your attention.